The Review of Smart Clothing Design Research based on the Concept of 3F+1I

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Abstract

Under the impulsion of the power of science and technology, the whole countenance of society has been changing. People's lifestyle has altered profoundly. As "a sort of second skin"of garment, the content of science and technology grow with each passing day so that the extension of clothing continues to expand. The traditional theory of fashion design is increasingly stretched when faces the impact of emerging technologies. In the face of the sharply rising proportion of science and technology, a comprehensive, in-depth and systematic research of smart clothing which is a growing field about intersection between fashion and science and technology, such as electronic information, should be done urgently. With that, the study will start from the perspective of garment for intelligent and review the combination of art and technology in fashion design. Based on the traditional theory of the fashion design, the study is to comb, analyze and redefine the concept, range and characteristics of the new field about intelligent clothing. Then, it is to summarize the general design pattern of smart clothing and establish relatively independent theoretical system of intelligent garment design. What's more, it mainly discusses the aesthetic expression of art and technology, and combines information technology, fabrics and accessories, structure modeling, process of production with aesthetics, art, design, psychology and the theories of other related disciplines. Meanwhile, it goes through further research of intelligent clothing on art aesthetic, scientific aesthetic and technical aesthetic. With the help of the aesthetic creation of science and technology, the study tries to make up for the deficiencies in academic basis for fashion design, and puts forward the design idea of 3F+1I，that is the design principle regarding fashion as the core, function as the key, comfort as the requirement, interactivity as identity. Thus, it provides standard and evaluation of smart clothing and puts forward the existing problems in the development of smart clothing. In brief, the aim of this study is to provide design methods, scientific basis and theoretical basis for research and development of intelligent clothing.

Keywords: Smart Clothing, Wearable Technology, Design System, Art, Science and Technology

Introduction

"The rapid fusion of fashion and technology will let stylists more dependent on the Cisco Systems, rather than Chanel."Forbes pointed out in the special edition of the development of future fashion. Science and technology and clothing in the most period of history have relatively independent development venation. Since the 20th century, due to the evolution of social productivity improvement and economic system, also their own developing logic, making close relations between two of them. Science and technology integrate in clothing gradually. In this day of globalization, the innovation of science and technology is leading a new revolution of fashion design in the future——Smart Clothing. Since the last century, people began to explore the future of clothing with a vision of the future and the yarn for future life. Smart clothing arose at the historic moment. Nowadays, smart clothing steps down from the "pulpit".

Once the blue sky thinking is not fantasy that people thought it was and each one of them has become a reality. The rapid development of high-tech and the Mobile Internet technology which is becoming mature prompted the combination of science and technology and clothing. People began to march to smart wear. They hope that the smart wear can change the future.

1. Analysis of the Research Status of Smart Clothing

1.1 Research Results

1.1.1 Foreign Research Status

The earliest study of intelligent textiles can date back to the 1920s. Then, they were gradually applied to space suits, uniforms and other smart clothing. However, the original smart clothing is not wearable intelligent textiles in the modern sense. It was regarded as a kind of equipment or tools to use. The focus on the design of clothing was to realize the function of "smart". Entering the new century, clothing and accessories with intelligence, environmental protection, science, knowledge, creation, discovery, enjoyment and quick as application orientation, using new thinking mode and high-tech means and creating a new world of smart clothing.

1.1.1.1 Military Field

Intelligence has become the eternal theme of military clothing, and extraordinary characteristics have also become the science and technology frontier of smart clothing in the future. Intelligent uniform is an important part of the development of intelligent clothing. Smart clothing was used first for military purposes as well. The multifunctional smart jacket——Superman battle suit, the muscular regimentals——wearing it can climb obstacles easily and the new type of "invisibility cloak" for the existence of camouflage have been put into the use of a new generation of intelligent uniforms.

1.1.1.2 Medical Field

Development and application of intelligent clothing in the medical field is relatively early. It is mainly used for the body physiological data monitoring or diagnosing diseases and plays a supporting role to the wearer's rehabilitation. There are smart medical shirt，remote monitoring T-shirt and optical fiber sensor shirt on infant monitoring in countries such as Spain, America.

1.1.1.3 Sports

The NuMetrex cardiac monitoring sports bra of American Textronics and the intelligent health socks of Sensoria both can track movement data through sensors, and then upload to the website or import personal mobile phone for data analysis. Experts also specially developed smart clothing for golf players and tennis player. Up to this day, smart clothing is not only limited to "Intelligent clothes", more and more wearable device also joined the ranks of the intelligent clothing. For example, Senso TRACK Headset and three intelligent Bracelet watches which launched by Fitbit have functions of monitoring.

1.1.1.4 Safety Protection and Positioning

The requirements of field exploration, survival in Arctic, extreme sports and so on the clothing are very high. It is necessary to make protection measures for safety and intelligent positioning. Since 1988, Finland began the research on Intelligent rescue clothing, and then gradually developed the smart clothing which can measure human physiological data and save life. And then MOTOROLA launched safety protection and entertainment and leisure in the integration of electronic ski jacket.

1.1.1.5 Entertainment and Leisure

As early as 1997，Philips and Levi 's were succeeded in creating the world's first set of wearable devices of smart clothing contained the function of entertainment and communication. The field for the application of the intelligent clothing opened up a new world. Then, Nike marring with iPod, iPhone and Google maps launched the intelligent series of sports products. And then wearable device was rising. In 2013，Samsung launched the Galaxy Gear intelligent watch products. Smart watches, smart glasses wristbands, smart headphones and other products appeared in the 2004 international electronics show CES exhibition. In September, Apple also released Apple Watch.

1.1.1.6 Beauty of Decoration

Using the unique optical fiber materials and paint to design different patterns and achieving the changes in clothing style and color through the shape memory materials and photochromic materials. International brands such as Burberry, D&G, Chanel have also used high-tech live women's conference. In May 2014,the Dutch new generation designer——Anouk Wipprecht, brought a visual feast for people. Every piece of his clothing can interact with surrounding environment.

Nike, Adidas, Lulu lemon and other famous brands have been marching toward the wearable technology market. Intel aim at spring/summer 2015 fashion week in New York and cooperate with "opening" to launch a smart bracelet.

1.1.2 Domestic Research Status

Hong Kong Polytechnic University was the earliest domestic focus on the research and development of intelligent clothing. It played an important role in the research of the textile and garment and commercial application. At the same time, many enterprises in Hong Kong and fashion designers also maintained close cooperative relations with each other to devote themselves to the market operation of smart clothing. In 2009, Shanghai ShenJiu began to manufacture the medical care smart clothing. In addition, the academy of fine arts of Tsinghua University also began to focus on the forefront of international technology and design. They cooperated with American, Holland and other countries and completed the design of a variety of intelligent clothing. In 2013, Beijing Institute of Fashion Technology developed a "not lose" smart shoe with functions of GPS remote positioning and other humanized functions . In 2014, Baidu announced that they and 361°，a well-known sports brand, have made a degree which they reached a strategic cooperation in the Baidu World Conference of the new marketing forum. The two sides will start a multi-level cooperation in large data field and set up a large data innovation laboratory so that it can promote high-tech research and development of intelligent products.

The research development of smart clothing is late in our country. Compared with the developed countries, there is little independent innovation research in China. Most of all are about the intelligent technology research in the field of fashion design. The theoretical research in the field of intelligent garment design is not yet mature. It still stays in the initial stage of exploration. Smart clothing has not fully entered the real people's lives. But the research and design of intelligent clothing field represents a development direction of future clothing. Smart clothing will develop and lead the new trend in the future. The research on the theory and application of smart clothing in China needs to catch up with the international advanced level and build intelligent garment design system in conformity with the development trend.

1.2 Problem

Under the background of new era which driven by the high-tech industry development. Smart clothing has become a hot topic in the research field of clothing. According to the statistical analysis that Wanfang database showed (Figure 1), from 2002 to 2014, the research of intelligent clothing appeared peak several times. Then the wearable products keep pace with smart clothing. By 2014, the amount of literature on the keyword "wearable" has surpassed "smart clothing". It shows that the combination of technology and fashion has opened up new prospects for the trend of the world. The present progress of science and technology become a driving force for the further research and the development of smart clothing.
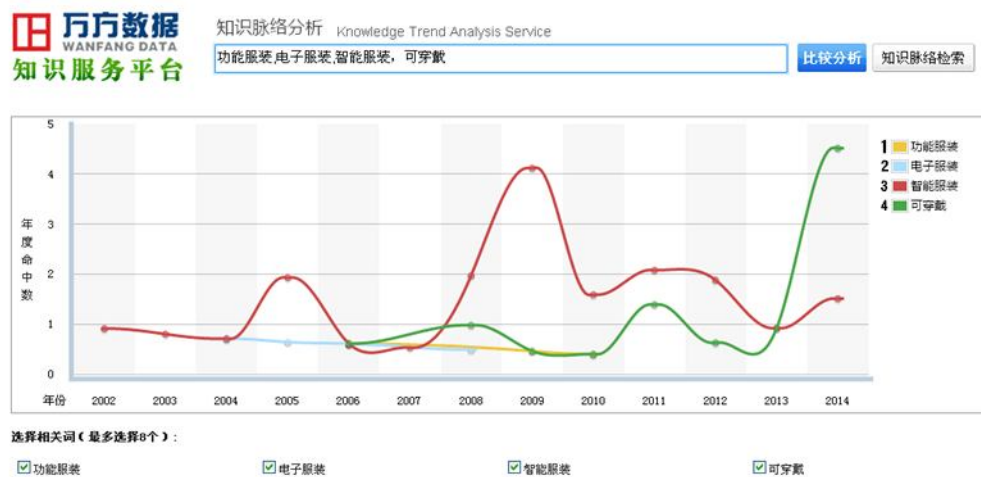

Figure 1: 1 Functional clothing, 2 Electronic clothing, 3 Smart clothing, 4 Wearability

1.2.1 The Definition of the Concept of Smart Clothing

Through the literature study and research status at home and abroad of intelligent clothing, the author found that, the definition of the concept of smart clothing is not yet perfect because the smart clothing is still in development now. When it comes to smart clothing, it will be associated with the technology of garment, electronic clothing, functional clothing and wearable equipment or technology. Under the above several conceptual understanding, the concepts of smart clothing and clothing with characters of intelligence are confused. The author will distinguish above concepts and re-define the concept of smart clothing.

Firstly, the so-called intelligent is one or a few aspects of applications among the modern communication, information technology, computer network technology, industry technology and intelligent control technology. Therefore, simply, the design involved in one or a few aspects of applications among the modern communication, information technology, computer network technology, industry technology and intelligent control technology is clothing with characters of intelligence.

Secondly, for the smart clothing, definitions are used in the literature [1-2] is that, smart clothing is refers to the simulation system of life, not only can feel the change of external environment or internal state, but also can respond to the change of clothing through the feedback mechanism. Smart clothing in the literature [3] is a product of textile materials and electronic technology model combining, which refers to clothing generating some functions automatically can change with the outside and perceive. Concept in the literature [4] is that, it is the product of combining the microelectronics technology and clothing, not only can collect signal according to the preset time, but also can deal with the signal and feedback. As a consequence, intelligent clothing can describe that it can change its properties according to external conditions or factors with a ability of storing and transferring.

In the literature [17-18] the technology clothing is the fusion of science and art, one of them provides dressers with self body monitoring measurement and control and other functions through the high-tech textile material except the completion of the traditional function. Another is the electronic products and clothing fused by adding, weaving and other binding mode. Dresser can be directly to enjoy and realize all kinds of interaction and perception of external environment condition. According to people's need to adjust and built environment. Electronic clothing, also known as electronic information products, and the literature [16] called washable type computer. It belongs to the second technology of clothing. In the literature [19] the so-called electronic clothing, it refers to a kind of garment products has all kinds of information transmission, storage and processing function. Functional clothing in literature [20], in terms of the function of clothing, one of its aspects can play a unique effect or it has long effectiveness. Wearable intelligent product introduced in the literature [5] is a kind of wearable computing device, and it can send and transfer information. It divides into wearable and wearing two types. Wearable devices in the literature [6], it is a kind of portable electronic devices that can be directly used as accessories worn on the body. It perceives, records and analyses by software.

Summarizing the literature [1-6] [16-20], the author thinks that the technology of garment, electronic clothing, functional clothing and smart clothing interrelate each other and also they have differences. (Figure 2)
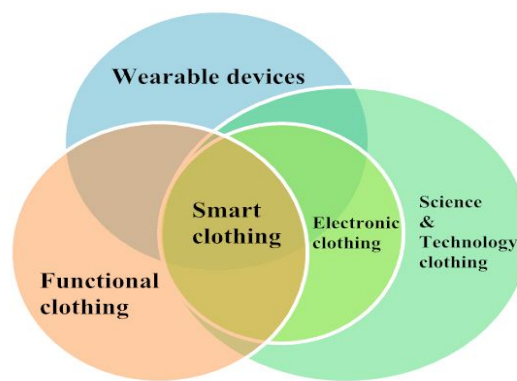

Figure 2: The Relationship of Smart Clothing, Functional Clothing, Electronic Clothing, Science & Technology Clothing and Wearable Device

The technology of clothing covers widely. The clothing in the science and technology can be reflected on the technology (The technology of clothing referred in the literature [17-18]）.It also can be a conceptual expression. Scientific beauty is a concept of the technology of clothing with the beauty of art expression. Beautiful shape reflects the sense of the future of science and technology. For example, The fashion modeling, color, accessories and so on are in line with the needs of science fiction in the American science fiction movie ——The Fifth Element. Jean-Paul Gayltier created the amazing vanguard fashion with unique and innovative way of thinking. He brought the viewer the aesthetic feeling of science and technology ahead of his time. Hussein Chalayan repeatedly used high-tech in today's life performance of technology and science fiction. He took advantage of the built-in mechanical to change the clothing modeling and used the built-in wires to make clothing produce photoelectric visual effect. It was full of mysterious beauty of art and science. These clothes were the creative expression of the conceptual design of technology of clothing. It was to change the shape of clothing under the artificial control. It was not the smart clothing on real significance, but can only be said to be the clothing with characters of intelligence.

Electronic clothing belongs to the technology of garment. It is the combination of electronic device and textile product. That is to say, all the electronic products whether in adaptation, integration or group and other ways on the clothing are electronic clothing. However, electronic clothing are not all smart clothing. Clothing is used as a carrier of electronic devices. If wearer don't interact with clothing, just regulate the electronic equipment to implement some functions of clothing, it is not the smart clothing on real significance involved in this study. The same is the clothing with characters of intelligence.

In terms of functional clothing, the definition of literature [20] has been more clear. It refers to the clothing can play a unique effect or has long utility on some aspects. Compared with functional clothing, intelligent clothing have many differences. Functional clothing only need clothing can work or have utility, not always have intelligent characteristics. For example，"Edible Clothing" is a new type of functional clothing for staffs which is suitable for the troops at the front, field trips, mountaineering, exploration and sail. What's more, disposable clothing, anti-electric clothing, all-weather clothing, bodybuilding steam suit and so on are functional clothing.

In general, once a part only emphasizes the function of "smart" will be eliminated. Starting from the definition of smart clothing, contemporary and future intelligent clothing is one kind has interaction with the wearer, capable of sensing, feedback and response. At the same time it plays the function of intelligent. It can be intelligent combined with electronic technology, and materials. There is overlap among smart clothing, electronic clothing and functional clothing. It and wearable devices are unity. We can widely define the smart clothing. Clothing has a broad sense and narrow sense. In a narrow sense, it refers to various kinds of clothing that covers the torso and limbs.

In a broad sense, clothing includes not only the cover of the main part on body, but also the cover of human head, neck and limbs. According to the deeper and wider perspective to understand, clothing refers to the whole dress form. It is the complex of clothes, accessories, jewelry, hair and makeup that wearer and environment coordinate with each other. Therefore, the author mentioned intelligent clothing can be a concept in broad sense. It is a general term for the intelligent clothing and wearable devices of the two.

1.2.2 The Design Method

At present, in a wide range of literature to retrieve about smart clothing, the research directions are generally intelligent clothing from electrical, materials science, computer and marketing. However, the number of literatures about smart clothing from the perspective of design patterns and design method is relatively small. From the angle of the subject, the research of intelligent garment design is still the engineering design.

The literature [1] mentioned intelligent garment design patterns is around the user-centered design idea. It is emphasized that a mode of user-centered development. The literature [9] put forward the analysis and judgment based on market demand and trend for functional clothing design patterns. It combined with the motion characteristics of human body, physiological status and environmental factors. It determined the physiological demand of users in a specific environment for the further design like styles, fabric and pattern of functional garment. The literature [2] mainly mentioned design process and requirements of intelligent garment through introducing the design, research and development of intelligent clothing in Finland. The literature [7] made children's clothing design as the carrier. It proposed the principle of designing of a new type of intelligent children safety clothing based on the 1T2F concept and the development direction in the future.

The literature of [8] focused on the care of preschoolers by means of interactive concept and interactive technology. It aimed to study the interactive smart clothing based on the new media interaction technology.

In the literature [1-8]，almost all are related to the "design". But they focus more on the development and evaluation of the function of smart clothing. While they ignore that the intelligent garment design aesthetic is a manifestation of art and science and technology in the whole aesthetic perspective. As far as the author's concerned, there are still certain gap about the theory research and design in the field of intelligent clothing. There is not a set of more perfect system design for intelligent clothing. Smart clothing has been always on the basis of functional clothing and electronic clothing which involved in electricity, biology and material science. This research is the broad sense of the intelligent clothing. With the rapid development of science and technology, smart clothing inadvertently have been given a new meaning. Its development is not only limited to specialized subject domain. It also has entered the fashion field. Therefore, high-tech smart clothing should have a set of relatively independent and systematic design model and method. On the basis of fashion design, the research will integrate the design method of intelligent garment and establish a relatively independent design system according to the characteristics of smart clothing.

1.2.3 Evaluation Method

The domestic and foreign research history of smart clothing is not long, especially it is also just in the initial stage at home. Hence, there are a lot of problems on the research of smart clothing. After the establishment of a relatively independent design system of smart clothing, the appearance of smart clothing, wearability, comfort, security and other aspects need to be examined. The literature [1] is on the basis of the international research and development of new product whose performance evaluation adopts analysis system of protective clothing for level 5.It is applied to the evaluation of smart clothing respectively from basic physics analysis, electronic technology, climate chamber test controlled trials limited field test and clothing, clothing system field test five aspects to conduct a comprehensive evaluation. The functional apparel design criteria in the literature [20]，one is the "4F" principle that America scholar R.F.Goldman emphasize in clothing design development, and another is the scholars on aerospace medical engineering——Jia Siguang, put forward the evaluation of man-machine-environment system. Four levels will be measured from the comfort, safety, efficacy and tolerance limit. And in the literature [22-23] mathematical model of generalized fuzzy evaluation is used for clothing and wearable equipment.

The author thinks that the evaluation criteria of smart clothing in summary are not fully applicable to the study of this topic. Clothing and wearable equipment performance can't equate. The current international has not been established quantitative evaluation standard for smart clothing.

This topic is based on the design concept of smart clothing——3F+1I. It fully considers the similarities and differences of smart garment and wearable devices. Summarize about the evaluation standard of smart clothing.

2. Research Idea

2.1 The Design Concept

The design of intelligent clothing design is different with the ordinary clothing. Its particularity lies in the design of smart clothing is a comprehensive and multi-interdisciplinary subject. Its design and research field is very extensive. It is usually completed by the electronics and software engineers and some relevant personnel of human engineering, garment and textile science, materials science, industrial design and fashion design. The design concept of smart clothing——3F+1I in this paper is put out of the background. The concept of 3F+1I refers to the Fashion (Fashion Design), Function (Functional Design), Feel (Comfortable Design) and Interactivity (Interactive Design). The organic combination of the four runs through the intelligent garment design. It put clothing aesthetic, material science and ergonomics into areas of science and technology. Under the concept of 3F+1I，it will co-ordinate the design mode of intelligent clothing. Then make a comprehensive study and an evaluation of intelligent clothing.

2.2 Design Principle

The paper is based on the design concept of 3F+1I. It will make a comprehensive guide for intelligent garment design and build the design system. It takes fashion as the core, function as the key, comfort as the requirement and interactivity as identification. It reflects art and science mutually promote with each other in the design. It will use the aesthetic creation of science and technology to rich original costume design concept.

The integration of science and technology and fashion design gives us full consideration about fashion modeling, style, aesthetic feeling, structure, craft, materials, body effect, etc. On this basis, it gives the clothing more humanization and intelligent functions so that design smart clothing which do not break vogue. This makes the wearer experience the convenience of technology when they pursuit fashion. Also, they experience the science and technology when obtain the quality of garment.

2.3 Design Elements

2.3.1 Technology

Technology is a key element of design in the design of smart clothing. Technology determines the overall smart clothing. It directly affects functions, comfort and interactivities of intelligent clothing. It will also indirectly affect the appearance of clothing. Therefore, the promotion of technology is a double-edged sword. It should not only ensure the intelligent clothing wearable, but also try to hidden electronic devices in the intelligent clothing. This makes that the development of smart clothing will bring great opportunities and challenges to the technical design. From the current development and application of smart clothing, intelligent garment design involves the main technology of electronic information technology, computer technology, textile technology and 3D printing technology. How to apply technology to the design of intelligent clothing？ How to make science and technology for smart clothing overweight？ This topic will be on the theoretical method combined with technology innovation to make the main description.（Figure 3）
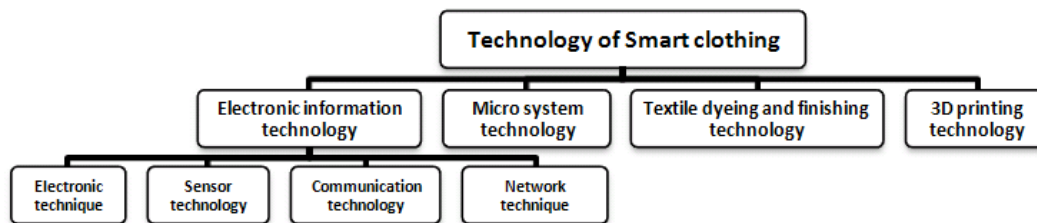

Figure 3: Technology of Smart Clothing

2.3.2 Materials

Materials undergo the transition from structural materials to functional materials to intelligent materials. The raw material structure of smart clothing materials become more and more upscale and diversified. Because of the particularity of smart clothing, the requirements for materials are differ from ordinary clothing. In addition to the basic function like covering the body, protection against the cold and beautification, but also it has the functions of automatic temperature control, automatic color changing and transmission of information and so on. This research is about the broad sense of the intelligent clothing. Therefore, in this paper the author will divide intelligent clothing material into the following categories: ecological materials, functional materials, intelligent materials and other materials. According to the definition of smart clothing, he design concept of 3F+1I and materials selection of smart clothing, smart clothing is broadly divided into two categories: intelligent materials smart clothing and intelligent function smart clothing. Intelligent materials intelligent materials smart clothing refers to the smart clothing is made directly by new intelligent materials (clever or smart material). Fabric itself joined the content of the information science on the basis of the original physical and functional characters. It has some functions that some organisms have such as sensing, processing, judgment, execution even automatic warning, automatic repair and stimulus response etc. Another intelligent function smart clothing refers to the material itself does not have the characteristics of intelligent, but combine with electronic devices.

2.3.3 Structure Model

The study of the structure model is to explore the aesthetic expression of art and science and technology in the design of clothing. By their nature, smart clothing is the embodiment of beauty of technology, beauty of function and beauty of aesthetic in the structure design. In this study, we will base on the aesthetics and give full consideration to the combination of the electronic equipment and clothing according to the rule of form beauty. It will take the uniqueness of smart clothing materials into account.

It will specially do some analysis for the overall design of structure model and local design to analyze, summarize and sum up. It makes beauty as a starting point and the unity between the form of the structure of smart clothing and function to provide suitable theory evidence for smart clothing structure design.

2.3.4 Color

Under such a system——people-smart clothing-environment, color is a factor to be reckoned with intelligent garment design. It has dual characters. It not only embodies the matching relationship between clothing and human plays a specific role in the technical function, but also plays a role in visual perception in the aesthetic creation design. The former is to express the rational content with specific color. For example, the smart clothing which is able to perceive the external environment change and change color because of the change of temperature, humidity, light, pressure and structure. Color can be used as interactive identification to express and transfer information. The latter is the perceptual content to use color to interpret emotion connotation. Color psychology is the subjective response of the objective world. According to the specific requirements of different areas of smart clothing, the design intent can be expressed correctly and clearly in smart clothing design with color psychology. On the basis of the concept of 3F+1I，the author will pay more attention to the color science of intelligent garment design in this study. Clothing change with the people's mood, spirit, action of expression or environmental conditions change. It reflects people's psychology, expresses emotion, gives the fashion sense and embodies the function of intelligent clothing through color. And then realize the important role of color in the "people-intelligent clothing-environment" system.

2.4 Design Evaluation

Whether smart garment meets the design requirements or not, sum up the following aspects need to be considered.

① Wearability. This paper will evaluate clothing comfort on the basis of physics analysis. It contains the fabric properties, such as permeability, hygroscopicity and wear weight, whether is easy to wear, anti-jamming performance, etc.
② Availability. The main task is enforceability, including electronic equipment is normal enabled, the overall operation of the system, the transfer, reaction, storage and processing speed of data, data connection and power supply capacity, the protection of personal information, error control range, etc.
③ Reliability. Special performance with different environment required, including the wrinkle resistant, waterproof, wear resistance, shearing resistance, high strength, strong tensile, warm, moisture absorption and so on.
④ Washability. Whether can wash or not, whether can normal use after washing, service life of the electronic products, dimensional stability of fabric etc.
⑤ Maintainability. It mainly includes the service life and replacement of the built-in electronic devices, battery charging, the system software update, etc.
⑥ Observability. The overall clothing design modeling, color collocation, concealment and rationality of the distribution of electronic components, etc.
⑦ Manufacturability. The estimate of cost price, the rationality of the design, whether to be applicable, etc.

Conclusion

The study will start from the perspective of garment for intelligent and review the combination of art and technology in fashion design. Based on the traditional theory of the fashion design, the study is to comb, analyze and redefine the concept, range and characteristics of the new field about intelligent clothing. And the standards which the intelligent clothing conforms to are summarized as the following：

①Perception. To perceive the external environment or internal state changes.
②Gnosis. To gather the signal according to the preset timing, store and transfer energy and information and make the processing of signal.
③Feedback. To perform a certain function automatically, react and adjust to change.

According to redefining the concept of smart clothing, sum up the general design patterns of smart clothing and put forward the design idea of "3F+1I"，that is the design principle regarding fashion as the core, function as the key, comfort as the requirement, interactivity as identity. Under the guidance of design ideas, put forward the design method for smart clothing according to the principle of design.

①Fashion of popularization

 Function of diversification
 Comfort of humanization
 Interactivity of intellectualization

Try to establish a relatively independent theoretical system of intelligent garment design and conclude design evaluation criteria of the intelligent clothing.

With the study of design and art, it provides a design method, scientific basis and foundation of theory for design of intelligent clothing research and development. Smart clothing is the crystallization of the rising of science and technology. Intelligent garment design is a multidisciplinary subject. Although the design of intelligent clothing still exist many problems, the future design leading the front of clothing art in the future development of the clothing industry. Intelligent garment design system will be more and more complete and systematic. The constant breakthroughs in technology, performance optimization of smart clothing and the application of the expansion of the objects make smart clothing really come into people's lives.

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